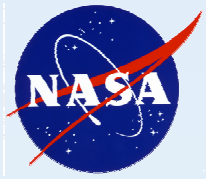


NASA GRC Icing Remote Sensing Activities

Andy Reehorst

Icing Branch, NASA Glenn Research Center

Outline

- Program philosophy
- This year's achievements
- Current plans/issues

Program Philosophy

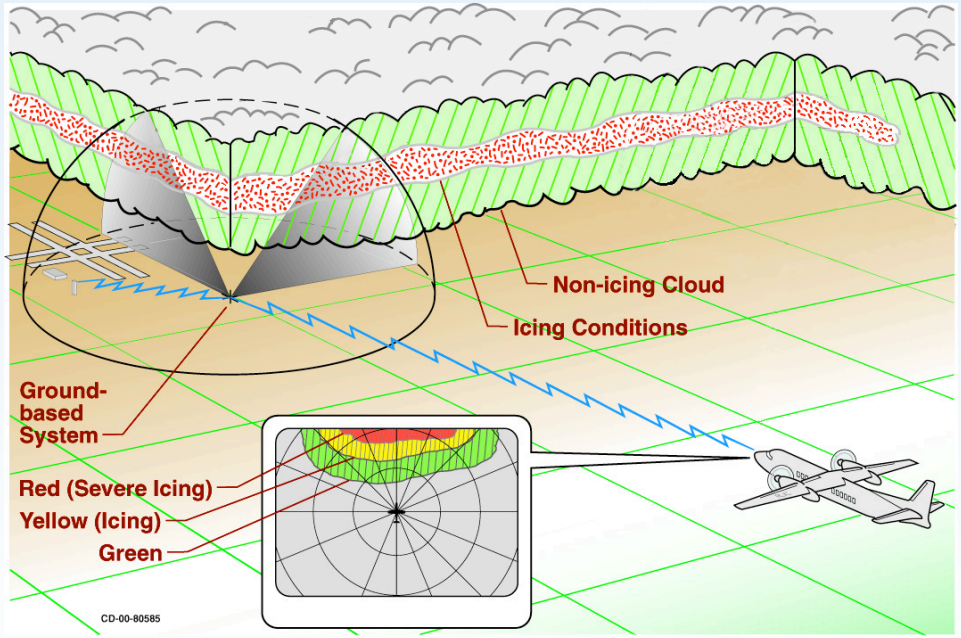
- Develop Remote Sensing Technology to improve icing-related flight safety
  - Enable tactical avoid and exit strategies
  - Improve strategic planning
  - Improve forecasts
- Fielded technology would aid flight-crews, airline dispatchers, air traffic controllers, and weather forecasters
- Focus on “low hanging fruit” for near term
  - Results in initially limited capability, ground based
- Later develop advanced ground based and airborne capabilities

Program Philosophy

- **Needed enabling technologies to remotely sense the presence of icing conditions aloft**
  - **Requires detection and measurement of liquid water**
  - **Requires measurement of temperature**
  - **Detection of exceedance conditions also requires measurement of droplet size**
- **Besides sensing technologies, development is required in**
  - **data encoding, severity characterization, data transmission (including up/down-linking), information display, and user training**

Program Philosophy

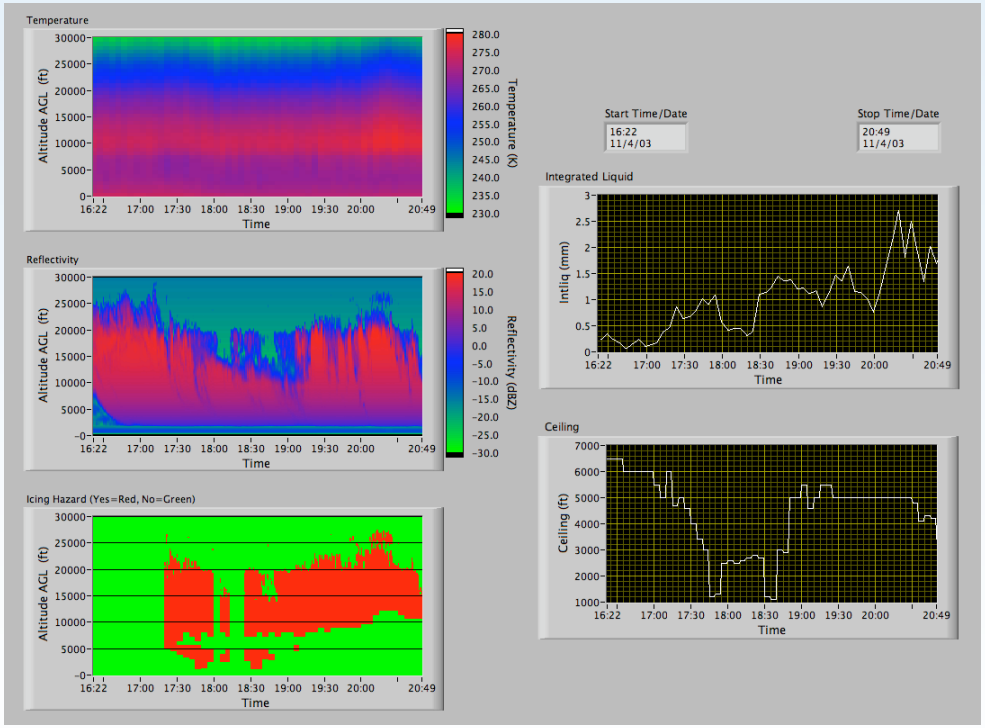
- Initially develop ground-based, vertical staring, terminal area sensing capability that can define altitudes with hazardous LWC/Temp
- Minimize cost, while providing relevant information
- Examine methods for information dissemination to aircraft
- Will also require future ground-based scanning capability to expand terminal coverage and airborne capability to provide coverage between airports



This Year's Achievements

Generation 1 NASA Icing Remote Sensing System post-processing software

- Uses X-band and ceilometer to define cloud boundary
- Uses TP/WVP-3000 to determine temp profile
- Uses TP/WVP-3000 to determine water path
- Distributes LWC uniformly over cloud region
- Thresholds hazard as supercooled LWC > 0.1 g/m^3



This Year's Achievements

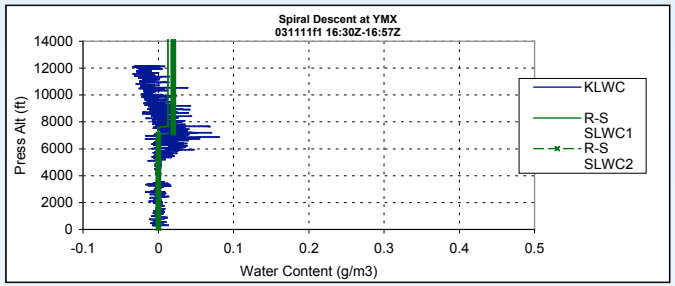
AIRS II

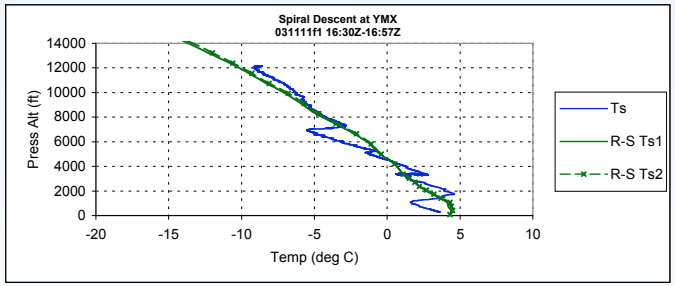
- NASA provided X-band, TP/WVP 3000 radiometer, 89/150 GHz radiometer, ceilometer, Sippican radiosonde ground station and GPS sondes
- NASA instrumentation operated through IOP1, Nov 3-Dec 12, 2003
  - Radiometers and ceilometer ran full time
  - X-band for periods of interest

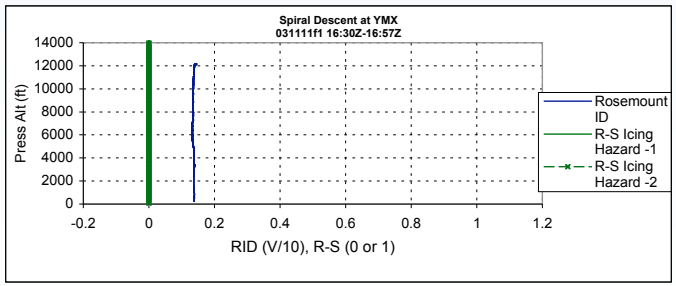
This Year's Achievements

Comparison to Twin Otter Data

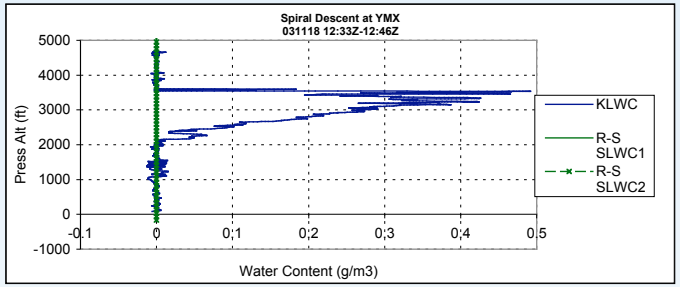
No liquid, all ice crystals

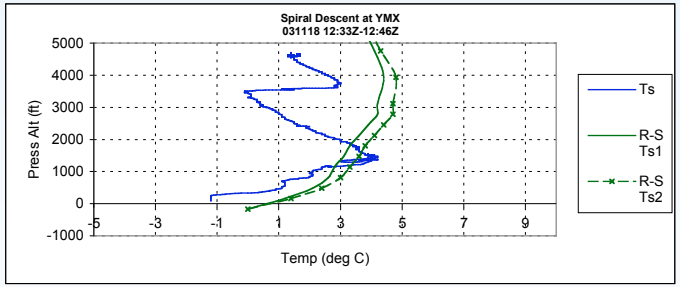


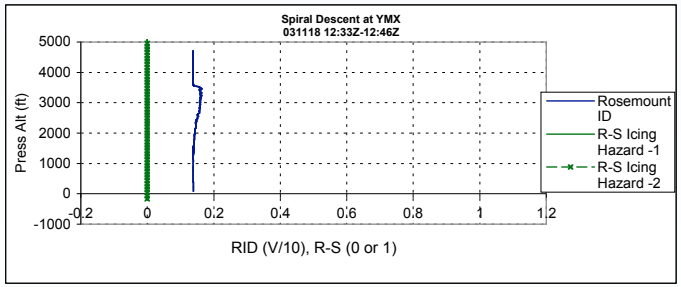




LWC above freezing



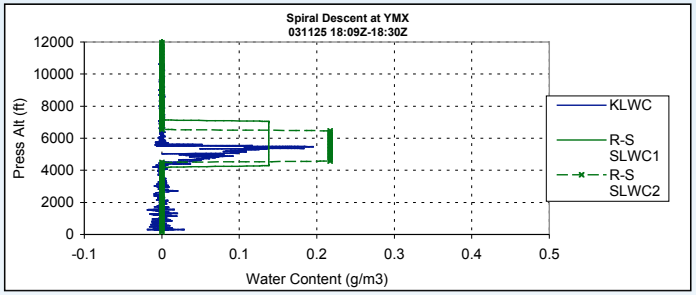


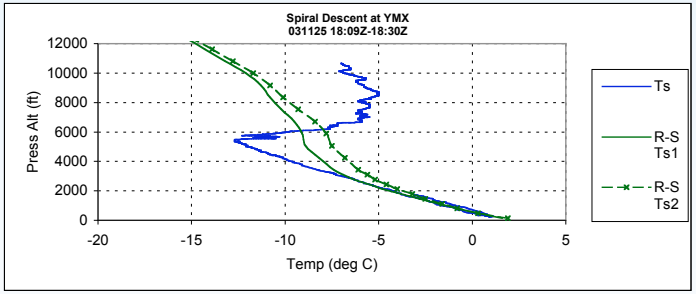


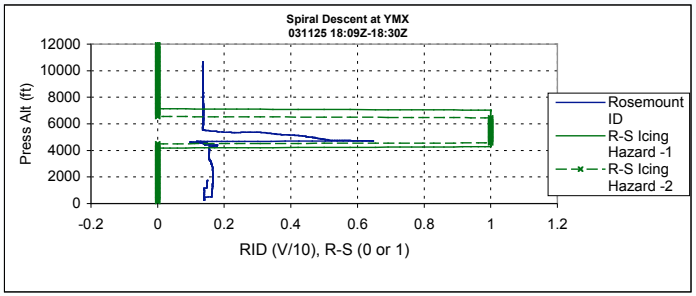
This Year's Achievements

Comparison to Twin Otter Data

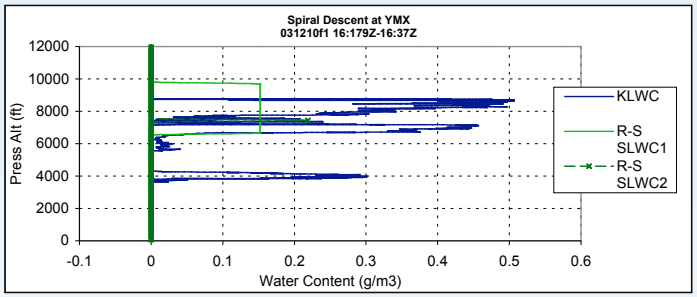
Light rime

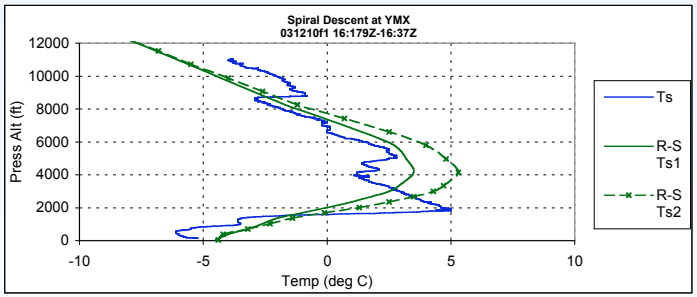


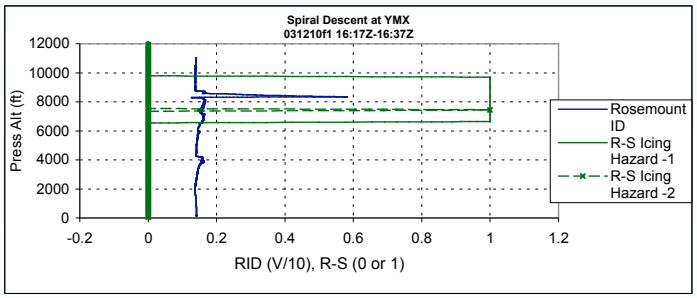




Light glaze, upper layer below 0°C

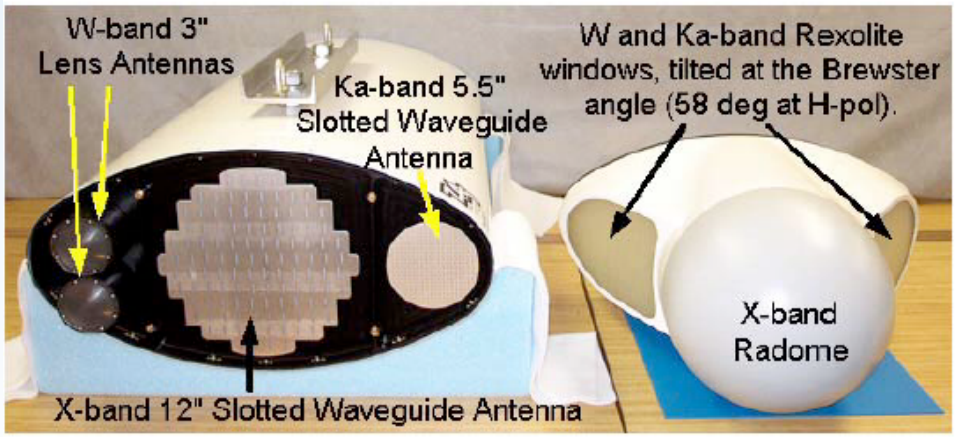


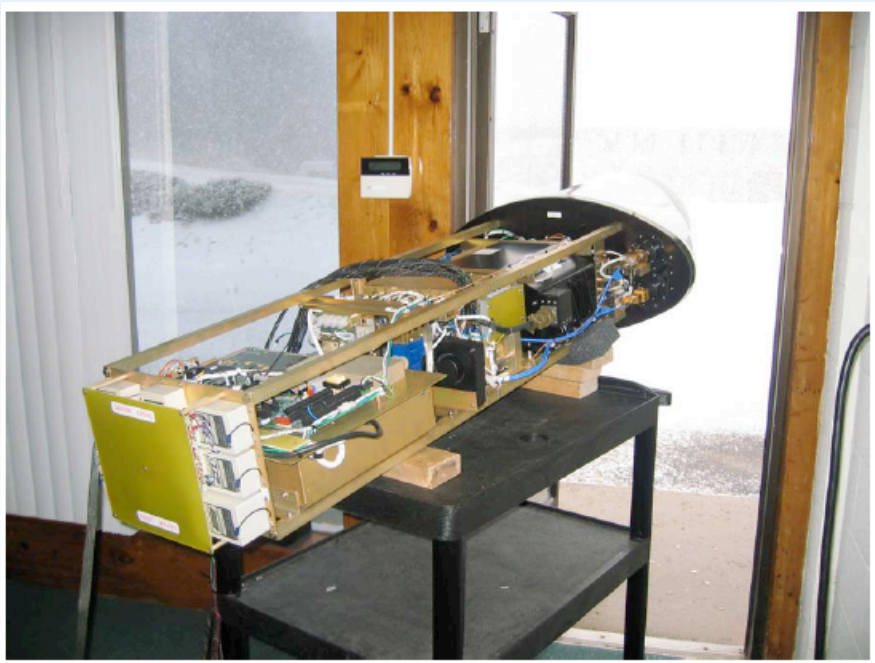




This Year's Achievements

Received ProSensing MFR





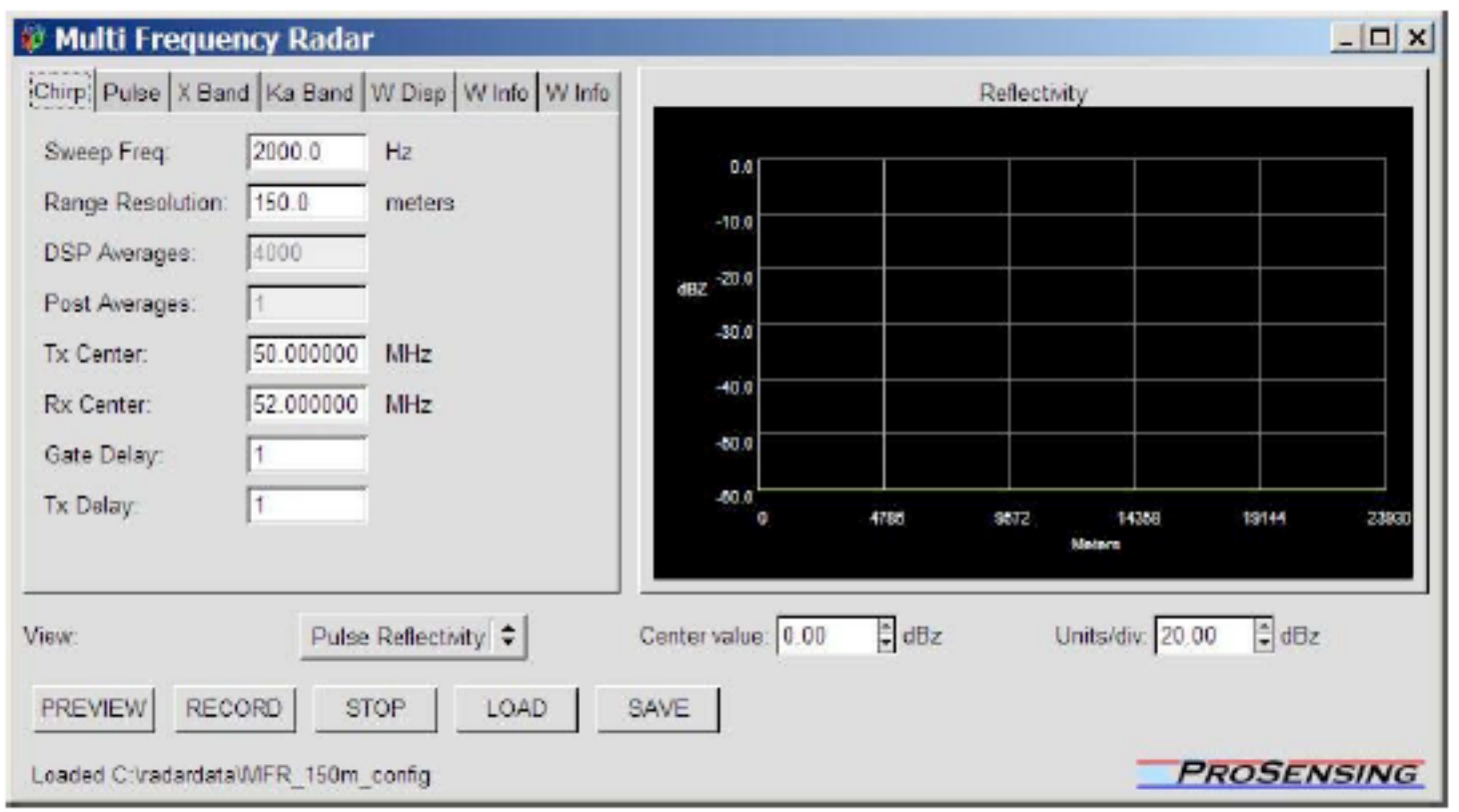
This Year's Achievements

ProSensing MFR specs

	X	Ka	W
Frequency	9.41 GHz	35.6 GHz	95.01 GHz
TX Waveform	Pulsed	Pulsed	FMCW
Peak TX Power	25 kW	21 kW	100 mW
Max. Ave. TX Power	25 W	10 W	100 mW
Antenna Gain	26.7 dBi	32.5 dBi	36 dBi
Antenna Beamwidth	8.1 deg.	4.3 deg.	2.9 deg.
Receiver Noise Fig.	4.8 dB	9.7 dB	6 dB
Range Resolution	150 m	75 m	15-300 m
No. of Range Gates	512	512	256
Recorded Radar Parameters	Reflectivity and Pulse Pair Doppler Velocity		
Power Requirement	115 VAC - 5 A (4 A typical) and 28 VDC - 8 A (6.5 A typical)		
Weight Pod Section	165 lb (Radar Electronics: 118 lb; Pod and Radomes: 47 lb)		
Weight Cabin Section	71 lb (Notebook PC: 8 lb; Controller: 19 lb; VXI: 44 lb)		

This Year's Achievements

ProSensing MFR controlling software



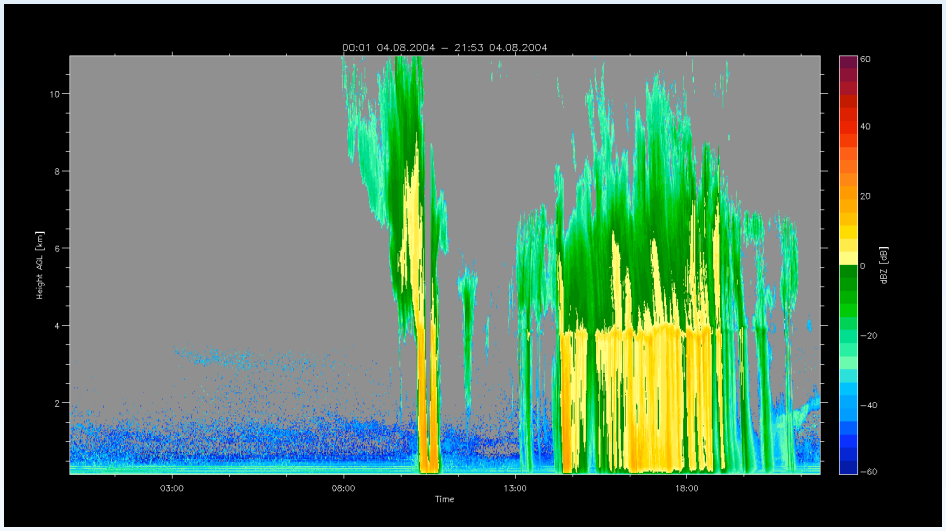
This Year's Achievements

- **Received Metek Ka-band radar**
  - 35.5 GHz
  - 30 kW
  - 200 ns pulse width -> 30 m resolution
  - 5kHz PRF
  - 150 m minimum height
  - 500 range gates
  - Sensitivity of -48 dBZ at 5 km (10 s averaging)

This Year's Achievements

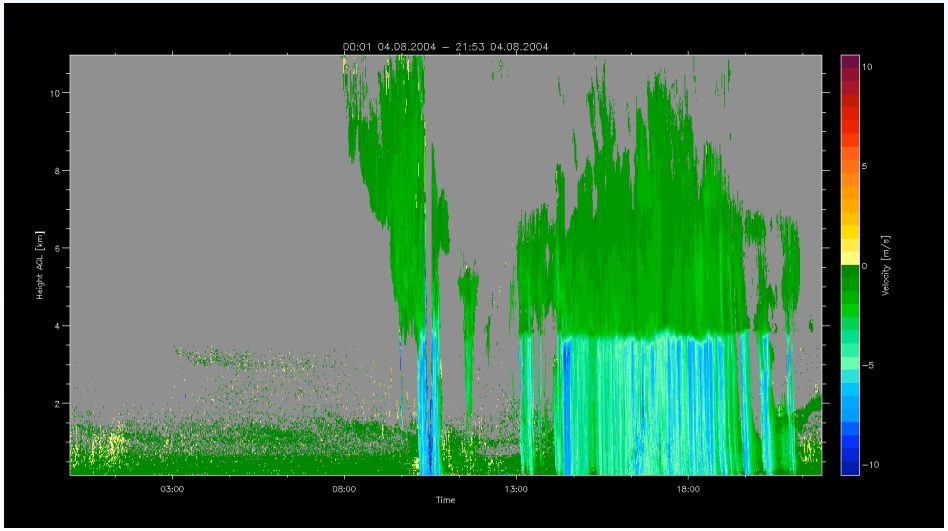
Metek radar output

Reflectivity



-48 dBZ

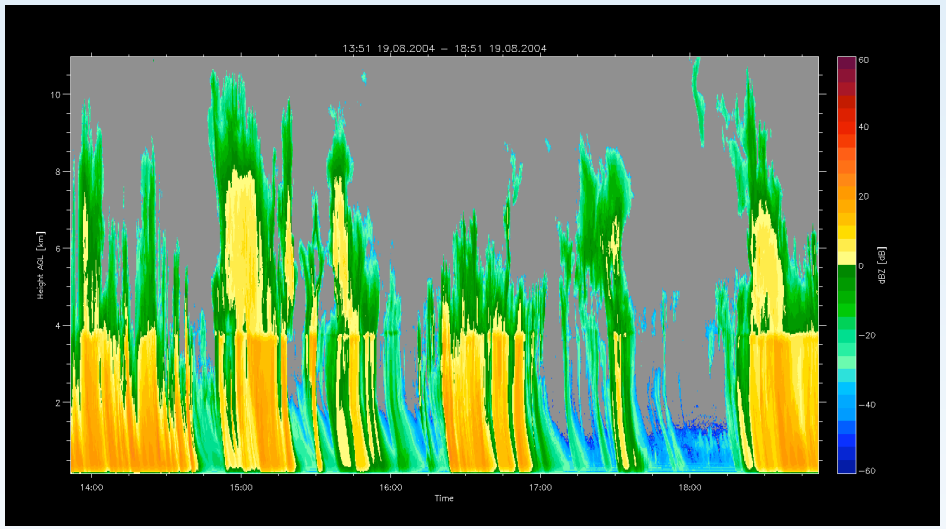
Velocity



This Year's Achievements

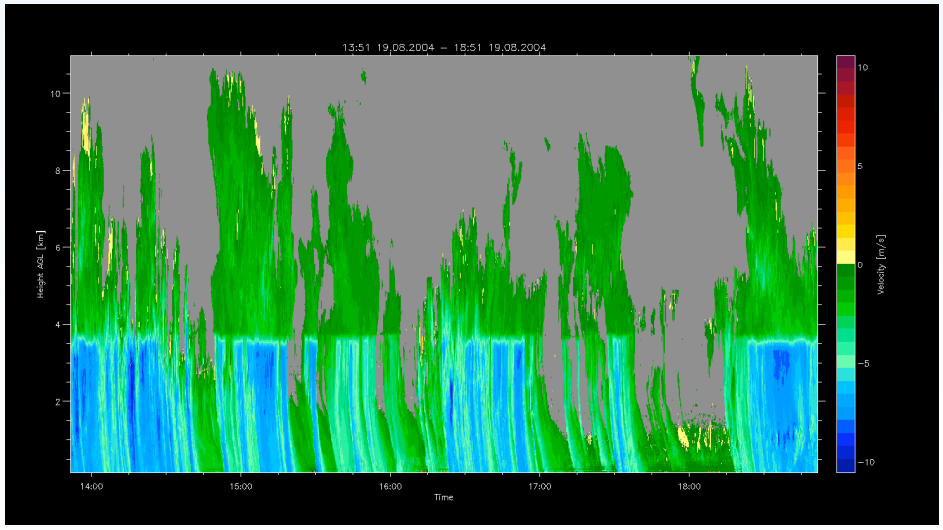
Metek radar output

Reflectivity



-48 dBZ

Velocity



This Year's Achievements

- **Radiosonde status**
  - **ATEK**
    - Jeff Hill is ready to 'go into production' with hardware
    - Waiting for Sippican integration of software
  - **NASA SBIR**
    - Hope to have a project running with a small business to develop an optical sonde instrument

Current Plans/Issues

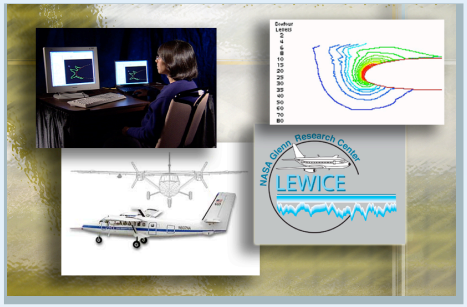
- **FY04 and FY05 Budgets [the BIG issue for NASA GRC]**
  - FY04 spending frozen in June
  - All aspects of the icing program de-scoped
  - This winter's field test pulled back to Glenn
  - Flight test prep eliminated
  - MIT grant eliminated
  - Pad extension eliminated
- **Generation 3 software (NCAR)**
- **Comparison of X-band radar/ceilometer cloud boundary definition to that of Doppler Ka-band radar**
- **Operate system(s) through the upcoming winter**
  - Compare to Twin Otter data and TCIP

FY06-10 plans

- **Funded Remote Sensing activity**
  - **Fused Icing Weather Systems**
- **Unfunded activity**
  - **Intelligent Aircraft Icing Systems**

Aviation Safety and Security Program

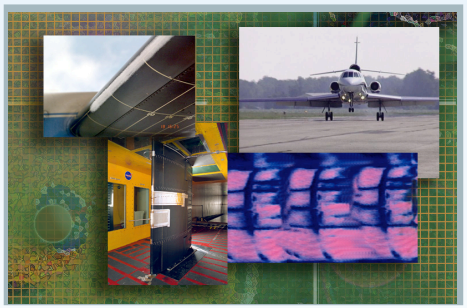
Fused Icing Weather Systems



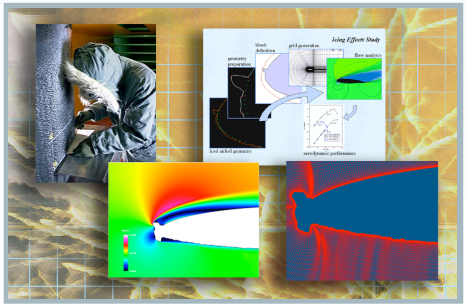
Icing Simulation Tools for Design and Certification

Demonstration of Intelligent Aircraft Systems

Advanced Ice Protection Technologies



Iced Aerodynamics Design Methods



Realistic Icing Training Environments Concepts

Fused Icing Weather Systems

Goal

- Develop technologies for sensing, fusing, and disseminating icing weather information to flight crews, controllers, dispatchers, and forecasters.

Benefit

- Improve flight safety by allowing strategic and tactical rerouting
- Increase aircraft utility by allowing use of more efficient flight routes

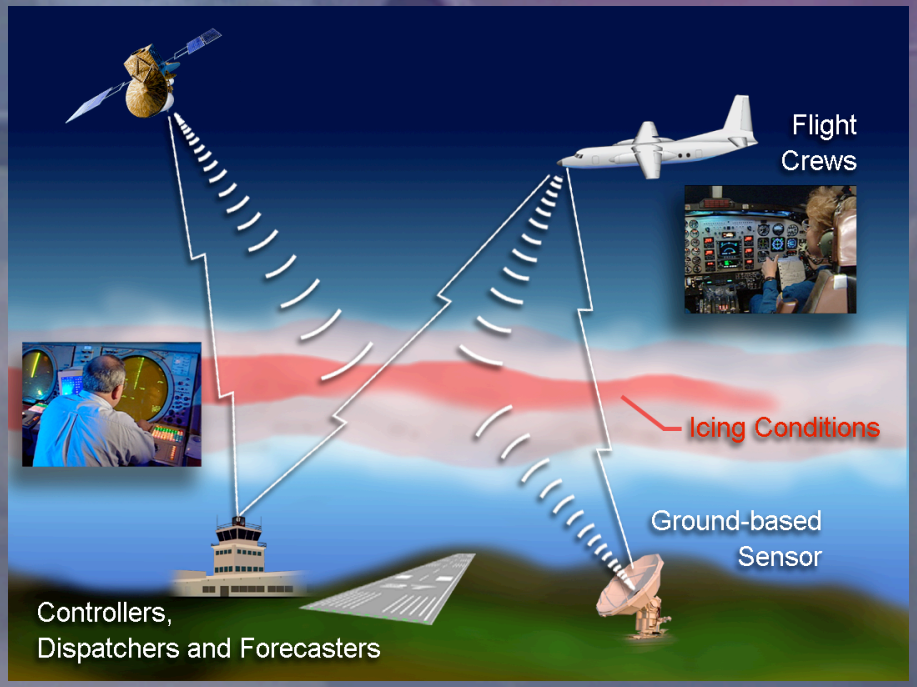
Approach

- Develop advanced remote sensing capability
- Develop fused icing product
- Develop icing product dissemination methodology

Fused Icing Weather Systems

Deliverables

- Complete terminal area coverage
- Airborne systems for coverage between terminal areas
- Integrated icing weather information package from ground, airborne, and satellite sources with hazard assessment



Intelligent Aircraft Icing Systems

Goal

- Develop accurate, real-time aircraft state monitoring in icing weather
- Demonstrate technology to determine icing threat level, evaluate flight path icing hazard, provide guidance if diversion or exit is required, and adapt flight controls if warranted

Benefit

- Quantitative icing hazard information to enable better pilot decisions
- Timely icing hazard avoidance or exit flight guidance
- Objective assessment of icing effects on airplane flying qualities
- Envelope protection for safe operations in degraded aerodynamic conditions

Intelligent Aircraft Icing Systems

Approach

Aircraft State Monitoring

- Accurate, real-time evaluation of performance and handling qualities, and control margins

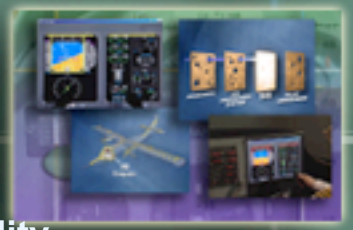
Operational Threat Assessment and Mitigation

- Technical process for determining icing threat and responding with dynamic envelope protection if needed

Icing Hazard Monitor and Guidance Systems

- Flight path hazard evaluation and flight director system for processing information and providing guidance

Intelligent Aircraft Icing Systems



Deliverables

- Accurate aircraft state and real-time icing hazard monitoring capability
- Flight director for avoidance or exit of icing conditions
- A validated technical process for icing threat assessment and dynamic envelope protection
- Demonstration of:
  - Icing threat monitor prototype - hazard & flight sim. models
  - Icing flight guidance system prototype